HARVEY AND HIS SUCCESSORS.

J. H. BRIDGES.

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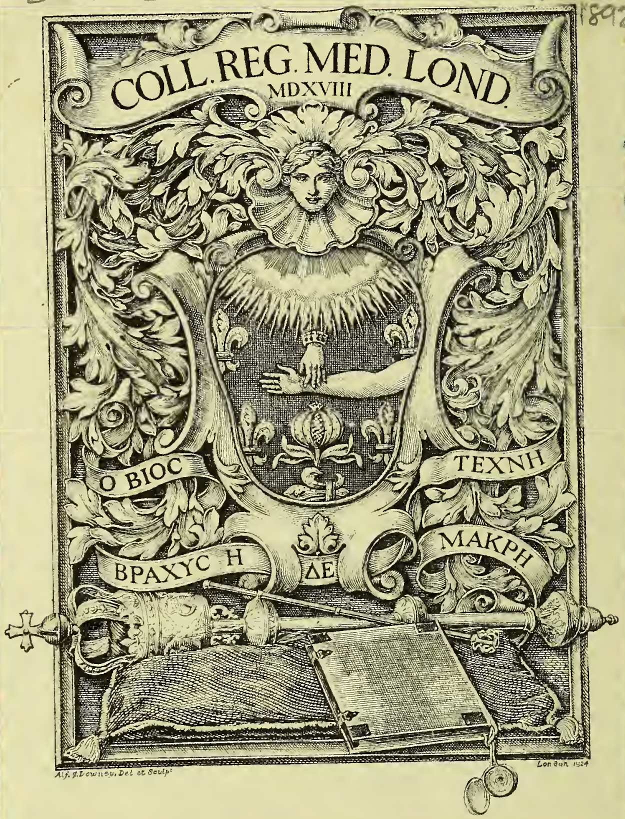
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HARVEY AND HIS SUCCESSORS

THE HARVEIAN ORATION DELIVERED AT THE

ROYAL COLLEGE OF PHYSICIANS

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BY

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WITH SINCERE RESPECT TO

SIR ANDREW CLARK, BART., M.D., F.R.S.,

PRESIDENT OF THE ROYAL COLLEGE OF PHYSICIANS.

HARVEY AND HIS SUCCESSORS.

Mr. President and Gentlemen,—Within a few days of Shakespeare's death William Harvey, physician to St. Bartholomew's Hospital, opened his course of lectures as Professor of Anatomy and Surgery at this College.[1] The rough notes used by him in these lectures were published a few years

[1] It were to be wished that Shakespeare's appearance were as well known to us as Harvey's; for there are many portraits of the great biologist besides that which faces the Harveian orator in the library of the College. These represent him at a somewhat advanced age. The two at Merton College—or, at least, that in the Warden's house—show him, probably, as he was in 1645-6, during his year of Wardenship. He was then sixty-seven years old. Of the fine portrait in the possession of the Master of University College, Oxford, inherited from his father, Dr. Richard Bright, I have the following description, kindly sent to me by its owner: "It represents Harvey with iron-grey hair, with a small, drawn, pointed face, with good strong brow and forehead, and rather delicate mouth: no sign at all of roundness. It is a remarkably thoughtful, almost suffering, face. The hands are singularly delicate, most beautifully painted, and with a good deal of character."

But in 1616 we may well believe that Harvey had the raven-black hair, vivid eye, and animated gesture, though not the "round face" of which Aubrey speaks. (See Willis's "Life of Harvey," ed. 1847, p. lxxv.)

ago by the College in facsimile, and few documents of greater importance for the history of European science have been given to the world in the present century. For not merely do we find in it clear proof of the completeness of Harvey's great discovery twelve years before the accepted date of its publication, but it opens a window through which we may watch the workings of a powerful and most original mind, and appreciate the breadth with which at a most critical period of scientific history he handled the problems of life.

In appreciating the life of a great man, as in that of the humblest protozoon, we have to bear in mind the essential fact of life first propounded by Comte and subsequently illustrated with such fulness by Herbert Spencer, that it is a mutual action, ever tending to adjustment, between organism and environment. The environment of higher organisms, no longer limited to the contact of surrounding particles, embraces all the social and intellectual influences to which a highly organized brain may be sensitive. Estimated in this sense what was the environment of Harvey? He was born at the greatest period of English history, not that of her world-wide empire, of her enormous wealth, of her crowded population, but the period in which she gave birth to her greatest men. Within the compass of Harvey's life there lived on this island Shakespeare, Spenser and the galaxy of Elizabethan dramatists, followed by the great epic poet, who was in his prime when Harvey died. In philosophy there were Bacon, Hobbes, Locke. In science there were Napier and Briggs, the inventors of logarithms; Harriot, the forerunner of the mathematical revolution of Des-

cartes; Wallis, the algebraical precursor of Newton; Gilbert, the founder of magnetic science; and that most fertile and ingenious of physicists, Robert Boyle. If statesmanship were in question, it would be sufficient to name Elizabeth and Cromwell.

Passing from England to the Continent we may say that Harvey was born into the full splendour of the philosophical and scientific Renascence. In art the Renascence had set in a century before, under Ariosto, Raphael, Da Vinci and others. The awakening of science was not slow to follow. Thirty years before Harvey's birth, the "Revolutions of Celestial Bodies" had been published in the last month of its author's life. The work of Copernicus was carried on during Harvey's youth by Tycho Brahé and Kepler. The cometary genius of Bruno was flashing through the universities of Europe, preaching the gospel of the new astronomy; and with a yet greater man than these the young Harvey was brought into near contact.

In 1597 Harvey took his degree at Cambridge, at that time a school of no great importance; in the following year he went to Padua, and studied under one of the greatest among the many great anatomists of that century and country, Fabricius of Acquapendente. Six years before this time a young man had been appointed to the professorship of mathematics in that university who was to open a new epoch in European thought. Galileo Galilei had already made his mark in his native city of Pisa. He had studied medicine under Cesalpino, chafing no doubt under his interminable pedantries. He had made his brilliant discovery of the equality of time in the oscillations of

the pendulum, and had applied that discovery, by a pendulum of suitable length, to the study of the speed and regularity of the pulse; the first instrument perhaps ever constructed for the precise observation of phenomena in a living organism. He had already done fierce battle with the powers of darkness in attacking the petrified philosophy that was called Aristotelian, and in laying the foundation of the true science of motion. The mathematics in which he was interested were applied mathematics; the interpretation and measurement of physical forces. From the beginning to the end of his life his unfailing conviction was that the phenomena of motion and energy which constituted the world were calculable quantities. The very use of the word "mechanics," to denote the abstract sciences of static and dynamic, dates from his treatise, published in 1593, on the "Utility of the Scientific Study of Machines." In this work the great modern conception of the conservation of energy is, I believe for the first time, traceable in his discussion of the paradox that the smaller weight on the longer arm of the lever balanced the heavier weight on the shorter one. "Philosophy," he said, "is written in the great book of the universe, which lies always open; but we must first understand the language and the character in which it is written; that language is mathematics. Without it we cannot understand the words, and wander through a dark labyrinth without a clue."

His lecture-hall in Padua held 2,000 students, and was crowded with strangers from every part of Europe. He had the art of forming a school and of attracting young men round him. Torricelli, the first measurer

of atmospheric pressure, was one of his pupils. The thermometer, first invented by Galileo himself in an imperfect form, was completed by another pupil shortly afterwards. Of the telescope I need not speak; and again it must be repeated that Galileo took the first step to that all-important condition of science—the precise measurement of time. In a word, the science of physics was founded by Galileo.

Of personal intercourse between Galileo and Harvey we have no record, but that the influence of his mighty genius is to be taken into account as one of the incident forces which moulded his mind there can be no doubt whatever. He came back from Padua with the sense that nature was not merely to be observed, but measured. He had imbibed elementary truths as to motion and energy which stood him in good stead when he began himself to think on the mechanism of the human body.

Let us briefly review the condition of biological science at the close of the sixteenth century. It may be summed up in one sentence—an advanced state of descriptive anatomy; hopeless confusion as to the functions of the organs described. The debt we owe to the descriptive anatomists of the sixteenth century has perhaps never been adequately recognized; though Vesalius, Eustachius, Fallopius and others have left their names inscribed on various structures of the human body. They were the worthy successors of Galen, whose works are themselves a cyclopædia of the anatomical and medical knowledge gained in the schools of Alexandria, enlarged by his own observations and experiments. In the schools of Padua, Bologna, and Pisa every part of the body was dissected

and scrutinized as minutely as was possible before the invention of the microscope, and none more minutely than the heart.

But with regard to the functions of these organs, the confusion of men's minds was complete and seemingly hopeless. Physiological science was far below the level at which Galen had left it. Galen was a strictly scientific observer and thinker, inheriting the results of six centuries of Greek inquiry, from Hippocrates onwards, and pushing them forward with marvellous zeal. In the thirteenth century the great schoolmen—notably, Albertus Magnus and Roger Bacon—had shown themselves his worthy successors. They brought Aristotle's scientific researches into prominence, and held them up as models for imitation. Afterwards came a time of stagnation and retrogression. For several generations the professorial chairs of Europe were filled by men who worshipped Aristotle not as a keen observer of nature and a progressive thinker, but as an inspired prophet who saved them the trouble of thinking. Even their Greek science they read backwards. If Galen in the second century A.D. differed from Aristotle in the fourth century B.C., so much the worse for Galen. Thus, for instance, we find the man who is sometimes held up to us as the true discoverer of the circulation—Cesalpino of Pisa—rejecting Galen's admirable investigations into the nervous system, and reverting to the curious doctrine of Aristotle, that the brain was a refrigerator of the blood which had been raised to boiling point in the heart. Similarly on respiration, where Galen's views, though very imperfect, were far less wide of the mark than Aristotle's, Cesalpino had

no hesitation in following Aristotle rather than Galen. Pedantry, obscurantism, indolence account for much of this, but not for the whole. The doctrines of the Church had become inseparably intertwined with Aristotelian metaphysic and logic. To assault Aristotle was to proclaim yourself a heretic.

Now, by Aristotle and all his successors the heart was regarded as a furnace, or at least a reservoir of heat, by the agency of which animal heat was maintained and the food was concocted. It was regarded also by Aristotle, though not by Galen, as the *sensorium commune;* it was the first organ that arose in the embryo, it was the last to die; it supplied the tissues with that which made them sensitive. In the fifth of the "Peripatetic Discussions of Cesalpino" (sect. 4), we have the following thesis maintained. The soul, he says, is not made up of separate parts, each residing in a separate organ; nor does the whole soul reside in the whole body, but the whole soul resides in the heart. He quotes with approbation the view of Aristotle that the animal is a commonwealth of organs, the soul being the ruler of that commonwealth. The heart is the soul's court; and as in a community all things are done by the soul's decree, though the king does not intervene in each detail, so do all organs live by virtue proceeding into them from the heart. For instance, in the function of respiration, the beginning of the series of actions concerned is the heart's heat. The blood boiling up in the heart not merely dilates the heart and so produces the pulse, but it dilates the lungs also by sending into them a continual stream of heated blood. The lungs being thus enlarged, it follows that external air streams in through the

bronchi, and this we call inspiration. Thence results a cooling of the blood and a diminution of its bulk, as when drops of cold water fall on boiling oil. The lungs collapse and air is given out. This we call expiration. The heart's heat is thus the initial force in respiration.

The whole of this alchemistic apparatus set up inside man's body, the heart boiling the blood to the point of evaporation, the subtler spirit thus produced condensed in the cooling chamber of the brain and issuing from it in the form of nerves, the lungs acting as an additional cooler, so that the part of the blood which remained liquid might be brought to the right temperature—all this confused and complicated fabric melted away as a morning mist before the touch of positive science applied by Galileo to inorganic matter and by Harvey to living organisms.

Let us not be unjust to Harvey's predecessors. It is quite true, and it should never be forgotten, that certain partial anticipations of his discovery had been made in the sixteenth century. By Servetus and by Colombo the transit of the blood from the right ventricle through the lungs to the left side of the heart had been distinctly put forward as the most probable hypothesis; and it is also true that Cesalpino had shown that, in consequence of the arrangement of the mitral and the aortic valves, the flow of blood was from the left ventricle towards the various organs of the body. I quote his actual words: "There is a motion from the veins into the heart while its heat draws in aliment; and at the same time there is a motion from the heart into the arteries, because, owing to the position of the valves, the blood cannot flow in

any other way, for the same motion opens both apertures—that of the vein into the heart, that of the heart into the arteries." [1]

Combining the view of Servetus and Colombo with that of Cesalpino, it might seem that a true and complete conception of the course taken by the blood would be reached; but, as a matter of fact, by no physician or anatomist of the sixteenth century were they at any moment so combined. Cesalpino was aware, indeed, of Colombo's hypothesis, which may be found stated, as Sir G. Johnson has shown, in two passages of his works. But these passages are entirely dissociated from the foregoing quotation. For a coherent view of the movement of the blood as a whole we may search in vain. The substantial identity of the fluid moving through the vascular system was never grasped by him or by anyone else. There were, men thought, two kinds of blood—one which was perpetually being manufactured in the liver and thence sent to the right side of the heart as fuel or aliment for the heart to work upon; the other was the concocted fluid flowing from the heart to the tissues, part of it having passed to the lungs for cooling purposes, and part filtering through the partition wall dividing the right side of the heart from the left. When we leave the consideration of the motion of the blood and turn to that of the motion of the heart, we find Cesalpino, like all his predecessors, hopelessly in error. In his view the expansion of the

[1] See Cesalpino, "Quæstiones Peripateticæ," lib. v., sect. 5. This work was published in Florence, 1569. For a fuller discussion of this part of the subject the Harveian oration of Sir George Johnson in 1882 should be consulted.

heart with blood was the efficient cause of the blood's motion, this being produced, as we have seen, by the boiling up of the blood when exposed to the imaginary heat residing in the heart. He insists emphatically that the contraction of the heart was a mere collapse due to a temporary cessation of the boiling process. In death the collapse, he remarks, is complete; in the moribund it is nearly complete. To attribute any expulsive force to the heart in this condition would therefore be out of the question. Thus the pulse results not from systole, but from diastole. Indeed, the consideration of the pulse is the main subject in this chapter of Cesalpino, the question of the heart and its motions being quite secondary. It may be stated broadly that the conception of a complete circulation of the blood and the conception of the heart as a contractile organ exercising mechanical energy were alike foreign to him.

Nothing is more interesting than the vivid, pithy way in which the true view both of the heart and of the blood is expressed in Harvey's MS. notes. "The heart, when contracting, moves like a muscle," he says. "By the impulse of the heart there is a perpetual movement of the blood in a circle." Again, if I may quote the quaint mixture of Latin and English, "Constat per fabricam cordis sanguinem per pulmones in aortam transferri as by two clacks of a water-bellows to rayse water." The imaginary furnace that had been set up for so many centuries within the human thorax disappeared, and in its place there was an organ of definite construction, comparable with one of Galileo's machines, exercising a measurable amount of energy.

The overwhelming importance of Harvey's researches, the feature that marks them as an epoch in the history of modern science, is the positivity of their method. We pass from metaphysical haze into an atmosphere of reality, utility, certainty and precision. He uses every method of biological research, direct observation and measurement, experiment, and, above all, the great Aristotelian method of comparison ; an instrument of research created, so to speak, by biology, and one so potent in every branch of scientific investigation that, apart altogether from its application to medicine, the science of biology would deserve all the pains that have been spent upon it. It is to the use of the comparative method that Harvey himself explicitly attributes his success; yet to what an extent he used it could hardly be appreciated till the publication of the notes of his lectures. In these the anatomy of eighty animals examined by himself is referred to.

It has sometimes been said, especially of late years, that experimentation on living animals was the process through which Harvey's discovery was achieved ; but this, though it has been used as a potent argument before an uninstructed public, has always appeared to me an exaggerated view. I am not about to enter, even in the most cursory way, into the ethics of the subject. It was not imagined in Harvey's time that any ethical problem was involved in it. So far as I can find, the first to recognize the existence of such a problem, and to distinguish himself from his contemporaries by voluntarily accepting a certain measure of parcimony and restraint in experiments on living animals, was that great and successful

experimenter, deep thinker and humane man, Sir Charles Bell.[1]

But the question by what methods the discovery of the circulation was reached is one for the dry light of historical research. Harvey's MS. notes show, even more emphatically than his published work, that direct observation of the pulsating heart in the higher vertebrates taught him but little. "Neque visu neque tactu" are his emphatic words in these notes; "I could not follow the heart's motions by sight or by touch, though I watched them for hours together. Videte quam arduum et difficile discernere; see," he says, pointing at the moment to the experiment he was performing, "see how hard it is to distinguish by sight or touch as to dilatation or contraction, which is systolé which diastolé." When the animal was moribund and the movement slow, or when he operated on cold-blooded animals with a simpler form of heart, he was more successful. When the discovery had been fully made, and the business of convincing others of its truth began, vivisectional experiments were of use to him. But the principal paths that led to the discovery seem to me to have been—first, the conception of the heart as a machine, exercising definite and measurable force on the fluid which it contained; secondly, that for the first time there was an attempt to measure the amount of blood contained in the

[1] It may be well to explain that my own attitude on a very vexed and difficult question is, and has been for many years, that of a supporter of the present Act of Parliament against attacks from more sides than one, pending the establishment, not merely in England, but in Europe, of such ethical restraint as men of Bell's temper would recognize.

heart and voided with each contraction, the result being to show that the rapidity of the current, and consequently the mass of blood returning to the heart, was far greater than could be accounted for by new formation of blood resulting from ingested aliment; thirdly, a far more careful examination of the anatomical facts than had been made by Harvey's predecessors. To the careful study of the heart's valves the important discovery of the valves of the veins, due to Fabricius, was now added, and was for the first time interpreted. Finally the whole was illumined by the light of the comparative method, by the examination of the fœtal circulation on the one hand and of the vascular systems of the lower vertebrates on the other. The motto from Aristotle prefixed to his lectures shows that the comparative method was his guiding star.[1]

Leaving this part of my subject I pass now to the consideration of the effect produced by Harvey's discovery on the progress of medicine.

It was obvious that Harvey had struck into a new path. His discovery was assuredly the most momentous event in the history of medicine since the time of Galen. It was the foundation stone of scientific medicine. It was the first attempt to show that the processes of the human body followed or accompanied each other in accordance with laws as certain and as

[1] The motto is taken from the sixteenth chapter of the first book of Aristotle's work on the "History of Animals:" "The organs of human beings are less known to us than others: so that we must examine them by reference to those organs of other animals to which their nature is similar." I translate from the Greek, Harvey's Latin being obscure.

definite as those which Kepler was at that time revealing in the solar system, and Galileo in all moving bodies on the earth's surface. Henceforth it became clear that all laws of force and energy that might be seen to prevail in the organic world were applicable to the human body. As an engine performing work, the heart stood on the same footing as any of the ship-building machines the operation of which Galileo had so carefully studied in the arsenals of Venice. The action of fluids in closed vessels under pressure was investigated in Harvey's youth by Stevinus, and in his later life by Pascal. The results were applied at once to the contents of the human vascular system.

Still greater prominence was given to Harvey's achievement by the all-embracing philosophy of Descartes, which during the latter part of Harvey's life had secured dominion over the intellect of Europe, and which retained it through the remainder of the seventeenth and a large part of the eighteenth century. That Descartes was among the first to appreciate the importance of Harvey's work has been often mentioned. Yet the question has not so often been asked, Why should Descartes, absorbed as he was in a general philosophy of the universe and of the human mind, have taken special notice of Harvey? It was extremely rare for Descartes to mention the name of any contemporary. I cannot call to mind in his writings more than one or two instances of his doing so. The explanation, as I believe, is this. Descartes had put forward a vast scheme of evolutionary philosophy, in which all the phenomena of the universe were to be explained as resulting from successive differentiations of a primitive homogeneous matter to

which motion had been imparted. The scheme embraced the motions of the solar system, the forces of light, heat, gravitation and the phenomena of living beings—all these being conceived as successive differentiations of primitive rectilinear motion impressed on the ubiquitous ethereal substance with which space was filled. In his view there were no facts in nature which were insusceptible of explanation on mechanical principles, and which could not be deduced from such principles by a sufficiently powerful mathematical calculus. He had himself taken the first decisive step towards the construction of such a calculus in his Geometry, published in 1637, leaving further steps to be taken half a century later by the infinitesimal analysis of Leibnitz, Newton, and the Bernoullis.

In his treatise on the nature of man Descartes had seized on the facts of the reflex action of the nervous system as illustrations of the automatic mechanical process by which the most complicated phenomena presented to our consideration could be explained. He welcomed Harvey's discovery as a yet more conclusive example of the applications of the new philosophy. The course of the blood, hitherto conceived as governed by vital spirits, by a vegetative soul, or by some other metaphysical figment of a like kind, was now seen to be determined by natural forces, to be regulated by the same laws of motion as those which governed inanimate matter. We know from the immortal prelude to his "Philosophy," his "Discourse on Method," how high were the hopes which Descartes founded on the future of biological research. "Health," he says, "is the first of good things and the foundation of all other good things in

this life. For so close is the connection of the mind with the temperament and the arrangement of bodily organs that if there be any instrument for making the mass of men wiser and more skilful than they have been till now, I believe that medicine is the art wherein to look for it. It is true that the medicine now in use offers little that is strikingly useful. But though I have no purpose to disparage it I feel sure that no one, even of those who now practise it, will deny that what is known is but a mere fraction of what remains to be discovered; and that we might gain freedom from a multitude of diseases both of mind and body, and perhaps also from the enfeeblement of old age, had we sufficient knowledge of their causes and of all the remedies with which nature has provided us."

Thus it was that under the combined influence of Harvey's discovery and of the Cartesian philosophy the vision of scientific medicine, the application of the laws of nature to the art of healing, dawned upon the world in the first half of the seventeenth century. It is worth our while to inquire with what results. Comte has remarked on the fact that the two initial discoveries of physics and of biology, the law of falling bodies and that of the circulation of the blood, were made simultaneously; and he has contrasted the immediate sequel in each case. Galileo's discoveries led by direct roads on one side to Newton and scientific astronomy, on the other to Torricelli, Pascal, Boyle, Mariotte, Black, Watt. To what did Harvey's discovery lead, and why the difference?

The truth is that the medicine projected by the ambitious brain of Descartes was from the first fore-

doomed to failure. It aimed at satisfactory explanation of the facts of living organisms by the laws common to them with other kinds of matter; it recognized no phenomena exhibited by living bodies that could not be so explained. Biology was to Descartes a corollary of physics; it was not an independent department of science, with physics for a foundation, but having a superstructure peculiar to itself, requiring inductions of its own, methods of its own; it was a body of knowledge which was to be made amenable as soon as possible to mathematical treatment. This mode of regarding the subject imported into medicine a spirit of reality, of certainty and of precision which had never before belonged to it; but in each and every case the attempted solution fell short of the mark. There remained always a residuum that could not be accounted for in this way. Hence during the seventeenth and eighteenth centuries two opposing schools of medicine—the first fastening upon the lower, more general laws which were susceptible of precise determination; the second dimly recognizing the existence of certain higher and more special truths, which, however, they were unable to quantify or even to discern with clearness.

Before describing the opposition of these schools, let us take stock of the scientific material available for medicine in the middle of the seventeenth century. We have already seen that in all that related to mechanical force as applied either to solids or fluids the first great steps had been taken by Galileo and Stevinus. By Galileo's principal disciple, Torricelli, a discovery had been made the importance of which to medicine cannot be over-estimated—the discovery

that the atmosphere had gravity, and that its pressure could be precisely measured. For the first time in the history of medicine the mechanism of the respiratory function became intelligible. It was seen to be a simple result of atmospheric pressure consequent on certain muscular contractions which enlarged the thoracic cavity. To Borelli and to Mayow of Oxford the credit must be given of first describing the respiratory apparatus with unmistakable clearness and accuracy. To Mayow also is due the first, or nearly the first, attempt to explain the chemistry of respiration.

On the subject of heat, its formation, its propagation, its relation to mechanical force, and its connection with vital action, there was complete, or almost complete, ignorance. Descartes, indeed, with the prescient instinct of genius, had put forward the conjecture that heat, like light, was a violent, insensible motion of the ethereal substance pervading the universe. But no proof was offered, no relation of this insensible molecular motion to molar motion was indicated; and the conjecture was buried with many other far cruder hypotheses of this great philosopher, to be revived in our own century. On animal heat the beliefs of physicians were of the most fanciful kind, and were in no respect sounder than those which had prevailed since the time of Aristotle. Descartes—and Harvey seems to have been in the same case—was content with the old view that the heart was a spontaneous source of heat. By this heat Descartes—deviating here from the sounder view of Harvey—held that the blood on entering the heart expanded; such expansion being the principal motor

force which, when the mitral valve was closed, propelled the current of blood through the body. A full century was to pass before Black and Lavoisier were to place the study of heat on a scientific foundation.

The second great hiatus rendering a scientific grasp of vital facts impossible was the absence of anything that could be called a science of chemistry. We know life as a series of chemical changes, anabolic and katabolic ; old substances decomposing, new compounds arising in their place. This continuous metabolism, following predetermined paths, is the distinctive fact of living organisms ; that which most obviously demarcates them from inorganic matter. No event that takes place in a living body, no function of any organ, is intelligible without it. Yet of the chemistry of life Harvey, and the generation following Harvey, were entirely ignorant. A few metals had been added to the list of those found in the virgin state and known to the ancients, the principal alkalies and some of the mineral acids had been discovered and several mineral salts had been investigated. But no step of the first importance had been taken since the time of Paracelsus ; and, above all other deficiencies, there was no pneumatic chemistry. John Mayow, indeed, had a strong, though dim, apprehension of the fact that something was contained in nitrate of potash, of an ethereal volatile nature, akin to the respirable atmosphere and essential to the maintenance both of life and of combustion ; and I know nothing more interesting in the history of science than to trace in his works this clutching at the discovery of oxygen, which yet eluded his grasp and that of other searchers after truth for a hundred years.

The composition of air and water, the difference between air and other gases, remained undiscovered. Combustion was explained by the comprehensive though false theory of phlogiston, the ethereal substance endowed with negative gravity ; a theory destined to hold its ground so tenaciously that even Priestley, a century afterwards, could not escape from its shackles. The chemistry of respiration remained unknown. Harvey, to whom both the mechanism of this function and its chemistry were alike obscure, has told us in his printed work, and still more clearly in his manuscript notes, how obscure a problem the whole subject of the lungs was to him, how great an obstacle to his discovery. Before birth the lungs were not needed for the circulation of the blood. Why should they become necessary afterwards ?

As the scientific study of life presupposes a clear apprehension of these physical and chemical laws, it is abundantly clear that in Harvey's time a scientific conception of life was not possible. And since the art of medicine rests, or at least is ultimately destined to rest, upon biological science, it follows that medicine regarded as a scientific art—an application, that is to say, of scientific principles to particular cases—must have remained throughout the seventeenth and the first half of the eighteenth century extremely crude and imperfect. Nevertheless, in the seventeenth century the attempt was made for the first time to found medical art on such scientific laws as had been then discovered. Harvey was not, perhaps, the conscious originator of this line of action ; it was rather due to the stimulating influence exercised by the scientific philosophies of Galileo and Descartes. Still

Harvey's discovery of the circulation was unquestionably the starting point from which it proceeded. It is worth while, as I have said, to watch closely the course of this procedure. For if much is to be reaped from the history of truth, something may also be gleaned from the history of error.

Of Harvey himself we are told that after the publication of his discovery his practice fell off; the implication being that the propagation of a new truth aroused hostile prejudice and alienated those who had previously consulted him. Is there any valid proof of such alienation? By this College he was from the first held in profound respect; he enjoyed Royal favour so long as there was a king in England. Under the Commonwealth his old age was passed amid every sign of universal regard. I hope it will not be attributed to disrespect of so great a name if I suggest that among the reasons for diminished success in the practice of his art, one may have been that his great discovery reacted upon it unfavourably. Had that treasure of his Medical Observations, to which reference is so often made by him, been preserved to us, we should be able to answer this question with some certainty. As it is, we can but express a doubt whether the dazzling splendour of a new truth may not have brought about a temporary blindness to the old; whether this one function of the circulation, accurately and precisely determined, may not have seemed so overwhelmingly important, by contrast with the nebulous haze in which other functions were still enwrapped, that the observer was tempted to account for the myriad phenomena of disease by disturbances of a single organ, and lost his power of

regarding the organism as a whole, on which, nevertheless, the art of medicine has rested since Hippocrates, and must for ever rest. If this were so, it was not to be the last time in the history of modern medicine in which the two opposing processes of analysis and synthesis came into disastrous conflict; for that history records analogous reactions on medical practice of almost every important scientific discovery.

What happened in Harvey's case we do not and cannot know. But as to the effect of his discovery on subsequent theories of medicine we are not left in doubt. A school of medicine arose, commonly known as the iatro-mathematical, which numbered many distinguished names, and held its ground for nearly a century, avowedly based on Harvey's discovery, and having for its aim the explanation of vital phenomena by mechanical forces. Some of the most important representatives of this school may be here mentioned.

The first on the list is Giovanni Alfonso Borelli, born thirty years after Harvey at Naples, a professor of mathematics and of medicine at Rome and Pisa. He died in 1679. His great work, "De Motu Animalium," appeared the year afterwards. He was the first to analyze distinctly the operation of the muscular system, and to attempt to assign with mathematical precision the exact mechanical energy exerted by each muscle. Before his time it had never been realized that the bones were levers and that the muscular tissue was the moving power; the resultant action depending on the angle at which the force was exerted, and on the distance of the point of insertion from the centre of articulation. So long as the

problem was one of elementary statics he was on safe ground; but many of the problems handled by him needed a higher calculus than was in his possession, and here he made serious miscalculations. The important step was, however, to break ground in this new field, to regard muscular energy as a measurable quantity.

Borelli framed a careful and elaborate theory of muscular contractility, beginning with criticism of the explanations hitherto offered. The muscle in contracting shortens. What makes it shorten? Some had compared it with what takes place in a rope when a weight attached to it is lifted, and successive parts of the rope become slack as the work is done; but in the muscle the contraction is simultaneous throughout the whole length. Secondly, the contraction of muscle is not elasticity; this would imply previous extension, and shortening could only take place to the point from which extension started. But, thirdly, could it be said that the contracted muscle is in a state of strain, which being removed the muscle shortens? If so, effort would be felt in the state of rest; while if any exertion was made there would be a feeling of repose. Again, it had been suggested that muscles contract by animal heat, as hair and other animal substances contract on scorching. Of such a rise of temperature there is no evidence whatever. Once more, muscular contraction had been compared to the corrugation of worms or snakes, but this corrugation is itself the result of muscular contractions. Finally, he dismisses with scorn the view held by some that the process was not a mechanical one at all, but a vital one. "As though

nature," he cries, "could dispense with the laws of destiny fixed by divine wisdom!"

What, then, takes place when a muscle contracts? Some bodily substance, he conceived, is transmitted by the nerves to the muscular particles, creating an explosion or ebullition, as when oil of vitriol is poured on chalk, or water on quicklime. So long as this nervous juice continues to be distilled into the muscle, effervescence goes on, the fibres of the muscle are driven apart as by a wedge, and shortening of the muscle results. When the supply of nervous juice ceases things revert to their former state.

Borelli's theory of nutrition was equally mechanical. Over-estimating the force of the heart as a mechanical agent, he conceived the blood as rushing through the vessels with sufficient force, first, to drive away worn-out particles from the tissues and eliminate them through the pores or otherwise; and, secondly, to rebuild the tissues by wedging in new particles adapted to the shape of the pores, just as in mosaic work stones of various shapes are fitted each into its proper place.

This sample of Borelli's physiology will prepare us for his pathology. The central fact for the pathologists of that day was fever. What was Borelli's theory of fever? The accepted view was that it was a heat kindled in the heart. A fermentation was supposed to be set up in that organ, the result of which was to set free the spirituous and sulphurous parts of the blood, and thus to bring about the quick pulse and other phenomena of constitutional disturbance. "But where," asks Borelli, "is the proof that the heart is the scene of these chemical processes? What

warrant have you for saying that the heart is hotter than the rest of the body? I," he says, "have tested the matter with a thermometer and can find no difference.[1] As to ferments contained in the heart, the lining membrane," he continues, "is perfectly smooth, and a torrent of blood rushing through it would sweep the imaginary substance away with it. Besides, it is easy to show by injection of hot substances into the blood that heat will not produce fever. No; it is not heat that causes the rapid motion of the blood, but the rapid motion of the blood that produces fever. My theory of muscular action explains it. During fever the nervous juice is poured out into the heart and all the involuntary muscles in abnormal quantities and arouses them to increased action. After a time the voluntary muscles cease, from the same cause, to be voluntary, and these also are convulsed." Borelli was no doubt obliged to imagine some other cause at work to produce this excess of nervous juice. Either that juice was poisoned by some ferment in the glands which were richly supplied with blood, or the nervous tubules were mechanically obstructed and the fluid contained in them fermented. In any case the visible symptoms of pyrexia—the heat, the swelling, the redness, the pain—were due entirely to mechanical causes. The essential facts in fever were, in Borelli's view, facts of hydraulics.

His followers, Lorenzo Bellini and Archibald Pitcairn, carried out the same view in a still more systematic way. Their names may be forgotten

[1] This, by the way, is the first instance known to me of the application of thermometry to animal physiology.

now, but in their own day their fame was European. Pitcairn was a native of Edinburgh, and practised medicine in that city, where he was the leading physician. He had previously occupied a chair at two foreign universities of the highest repute, Montpelier and Leyden. In the latter city the illustrious Boerhaave was among his pupils. It is to Pitcairn that Lorenzo Bellini dedicated his work.

Pitcairn's remarkable work, "Elementa Medicinæ Physico-Mathematica," is a systematic treatise on medicine, beginning, as was usual at that time, with a statement of physiological principles. This is interesting if only as evidence of the overwhelming importance attached by his school to the discovery of Harvey. Life and the circulation of the blood are identical, he says; life *is* the circulation; there is no independent life of the parts. It is the body which lives, not any part of the body. Circulation, which is life, depends not on parts but on the whole. "Dividitur corpus in partes continentes et contentas, id est, canales et liquores." Vessels and the contents of vessels make up the whole substance of the body. The differences between one body and another were differences in the fluidity or viscosity of the contained liquids.

Then follows his explanation of what was rightly looked on as the fundamental problem of animal heat. He conceived heat to be an explosive substance locked up in certain particles of the blood, and liberated by the attrition of those particles; this attrition, of course, proceeding more rapidly as the circulation was more vigorous. The notion that animal heat resulted from a certain residuum of blood left in the heart, and con-

tinually fermenting, he scornfully rejected, as Borelli had done. There could be, he said, no such remnant. The lining of the heart was smooth, and the whole mass of blood swept through it and passed on. To invoke the chemistry of fermentation was needless. Mechanical causes accounted for the whole.

For the pathological fact of fever, or at least pyrexia, mechanics supplied sufficient explanation. "By the word fever," he says, "I understand the velocity of the circulation uniformly increased in equal intervals of time." Increased motion of the blood produces rarefaction, as blood flows more rapidly from capillaries to veins. On rarefaction follows increased secretion of nervous fluid; on this again increased action of the heart's muscular tissue, hence a quicker pulse, so that the effect of increased cardiac action also becomes its cause. The classical symptoms of fever—flushing, swelling, pain, want of sleep, convulsions, hæmorrhage, cutaneous eruption, parched tongue, thirst, anorexia, loaded urine—are each in turn explained as the result of mechanical processes.

Intimately associated with Pitcairn was Lorenzo Bellini, one of Borelli's pupils, who carried on the same line of research in an even more systematic way. The problem specially attacked by him was that of secretion, attributed by the chemical school of physicians to the action of ferments. For this school the familiar fact of fermentation, with its attendant phenomena of effervescence, heat, change of substance, etc., did duty as the one solitary representative of the vast domain now known as organic chemistry. It had very naturally and legitimately forced itself upon the attention of these men, offering as it did a prompt

explanation of a multitude of obscure facts. The liver was supposed to secrete bile by virtue of its ferment; so did the pancreas, so did the salivary glands, the kidneys, the gastric mucous membrane; nay, as we have seen, the fact of animal heat itself was supposed to be elucidated by an imaginary ferment residing in the heart and acting on the blood as it passed through. Everything could be explained in this way. Men soon become the slaves of words; and so here the word "fermentation" (which in reality held the clue—as 200 years afterwards we have come to see—to some of the hidden secrets of life and disease) became a mere metaphysical figment like the dormitive influence of opium in Molière's play. It solved hard problems by the simple process of restating them in obscurer and more pedantic language.

Against these crude chemical theories the mechanical school of physicians, with Bellini at their head, waged fierce battle. "What sort of an explanation," he asked, "do you arrive at by your theory of ferments? If secretion is caused by a ferment contained in a gland, then what is it that secretes that ferment? Suppose, for instance, that bile is secreted from the blood by some special ferment; that ferment requires a second ferment to secrete it, and that second yet a third, and so on without end." But in truth the whole of this chemical apparatus is, he maintained, unnecessary if we think for a moment what is meant by the cohesion of particles of matter. Two molecules press towards one another with a given force and in a given direction. Change the force and the direction, and we have a new arrangement of molecules—in other words, a new compound. To effect

this change some external force is needed, but this need not be a ferment; the action is mechanical, not chemical. Secretion is the separation of certain elements of an animal fluid from the rest. Now we see this separation taking place outside the body without these imaginary ferments, as, for instance, after blood-letting, in the separation of the clot from the serum. What takes place outside the body may take place inside. "See again," he continued, "what takes place when blood is placed in a vessel and subjected to Mr. Boyle's new machine for extracting the air. Ebullition and evaporation ensue; that is to say, certain portions of liquid at once separate from the others, which had previously been held down in contact with them by the pressure of the superincumbent atmosphere. So it is that inside the body changes of mechanical pressure suffice to explain all that takes place. A gland is simply a closed vessel with extremely small perforations of different shape and size. What takes place in it is as purely mechanical as what goes on in the formation of a blood-clot or the filtering of fine sand from coarse. There is not the slightest necessity for complicating the matter with ferments. *Deus naturæ conditor est Deus facilitatis* (God does everything in the simplest way)."

As time went on the potent mathematical calculus of Leibnitz, Newton, and the Bernoullis held out increasing hopes of being able to overtake the subtle processes of nature, and of anticipating direct observation by a reasoning process. Dealing with the infinitely little as well as with the infinitely great, prepared to represent every natural form, even the variations of each human countenance, by an alge-

braical equation, it seemed to them that they were entering on a path leading directly to omniscience, and surely capable of unravelling the intricacies of life and of disease.

It would be interesting, were there time to do so, and it would not be uninstructive, to trace the influence of this extraordinary scientific stimulus upon the great physicians of the early part of the eighteenth century, more especially upon Boerhaave, a pupil, as I have remarked, of Pitcairn, and upon Richard Mead. In Boerhaave's theory of fever the excited pulse indicated the effort of the heart to sweep away, as by a flood tide, the obstruction in the capillaries; and a similar attempt to explain biological facts by the mechanical forces of the circulation is to be noted in Mead's discussion of the operation of poisons. But these great physicians were preserved by the wise empiricism of their clinical instinct from the extravagances that beset more one-sided men.

Thus it was that the devotees of the two great sciences of mathematical physics and of chemistry—the one brought to a high degree of perfection, the other crude, imperfect, struggling to be born—strove strenuously for their exclusive application to the art of medicine. The iatro-physicists were far more fitly furnished than their adversaries with the armament of scientific discovery. They had arisen with Galileo and Harvey; they were carried triumphantly onward by Torricelli and Pascal, by Boyle, Newton and the Bernoullis. The great discovery of Harvey was their own domain; to extend its application to every bodily function was the goal of their efforts. The chemiatric school, on the other hand, could rely only on the

sinister though seductive memories of Paracelsus, and on the dawning hopes of a future which they were not to witness.

The struggle was watched by a third school of medical investigators, who saw weak joints in the armour of both the combatants. I refer to the animist school, which arose at the end of the seventeenth century under the leadership of Stahl. He was the most prominent chemist of his time. His hypothesis of phlogiston was accepted as a satisfactory explanation of combustion for three-quarters of a century. But Stahl felt, in a confused, dim, strenuous way, that the facts of life—the selective, coördinating, prearranging processes presented by the humblest animal or plant—were not to be accounted for by the play of mechanical or chemical forces. So strong were his convictions on this point that his Archè, or Vital Principle, dispensed altogether with mechanics and chemistry. It was a metaphysical figment, involving error at the least as gross as that against which he contended; but within the husk lay the germ of an all-important truth.

Later in the eighteenth century the discoveries of Black, Cavendish and Lavoisier fulfilled the preliminary conditions for the evolution of biology as a distinct science. Haller, Hunter, Bichat and others brought that science to the birth. From that time to this it has become more and more plain that physics, chemistry, biology are distinct sciences, with methods of their own and inductions of their own, each of the latter terms in the series using the results of its predecessor and adding new results of its own. Life is a structure built up of physical and chemical facts. Yet to the

building, to the arrangement, to the ordering of those facts there goes something that neither physics nor chemistry can explain any more than algebra can explain the behaviour of a magnet. To strive to interpret the series of events which make up the life of an animal in terms of chemical metabolism or of conservation and expenditure of energy is an endeavour which will fail; though it is a useful endeavour, because only thus can we eliminate what remains. That something remains the greatest of living British physicists has always maintained and has recently assured us. The admitted insufficiency, to take one instance from a thousand, of Lavoisier's theory of combustion to account for the phenomena of animal heat, the admitted necessity of seeking in the nervous system for a thermotaxic centre or centres to account for the amazing adjustments of the organism to changes of temperature in the environment, might suffice to convince the biologist that, though he receives his building material from the physicist, he must construct the edifice for himself.

The history of medicine is a strange and fascinating though sometimes a melancholy record. We see in the fifth century before our era a man of genius, gifted with that marvellous union of the observing eye with constructive imagination which astounds us in the sculptors of the Parthenon, building up without science, without anatomy, the fabric of medical art of which what we still practise is but the enlargement. Inheriting from the priestly guild from which he sprang a vast store of observations, and adding yet more of his own, Hippocrates was guided in dealing with them by two fundamental principles—(1) that diseases, like

other phenomena of nature, follow a natural sequence; (2) that the organism of man, however complex, is yet an individual whole, each part receiving and impressing reactions on every other. After Aristotle and Galen had done their work, long centuries ensued of blind and sterile routine, followed by a period of acute but one-sided analysis. By the help of such analysis it may be that the Hippocratic synthesis will be again built up on a more enduring basis.

The ideal perfection of medical art rests upon an equally ideal perfection of the science of human nature, summed up in complete knowledge of our organism and of the influences that act on it. The goal is unattainable, yet till it be approached the physician must be content with empirical knowledge of an infinite array of facts — biological, psychological, ethical, which, though certain as mathematics, yet do not admit of quantitative determination. It is only within the last generation that the word "subjective" has become familiar to the biologist. As the student of sensory organs deals with some of these subjective facts, so does the student of human passions deal with others, for these, no less than sensations, are functions of our organism. To determine the way in which this or that man will be affected by any morbid process without taking account of such facts is assuredly impossible. They must be taken into account at all costs; if not by scientific process, then by wise empirical instinct.

I shall conclude with saying that as medical art has been affected by the rise of physics and chemistry in the seventeenth and eighteenth centuries, so will it be affected by the scientific sociology of the nineteenth

and the twentieth.[1] Not till science has fully embraced every aspect of human life can medical art, as founded upon science, hope to be complete. But at the dawn of modern science in the seventeenth century the dazzling brilliance of mathematical and physical discovery led the keen and daring minds of whom I have been speaking to the belief that all phenomena with which the physician deals could be spoken of in terms of mechanics. It was a legitimate and inevitable stage in the progress of the human mind. Without it the later stages would have been impossible. It initiated the great discovery of Harvey, whom not merely we, but future generations, will continue to venerate as the principal founder of scientific medicine.

[1] As this remark perplexed some of my hearers, I would refer them to the 127th section of the first book of the "Novum Organum." It was because of Comte's attempts to carry out the programme there contained that G. H. Lewes, no blind adherent, spoke of him as the Bacon, and "something more than the Bacon," of the nineteenth century. That Comte was preceded, and that he has been, and will be, followed in those efforts by other thinkers is obvious. And it seems reasonable to suppose that better knowledge of Man will lead to better Medicine.

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